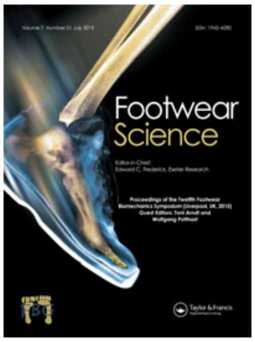

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Prediction of clinical foot characteristics using quantitative features from different measurement set-ups

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Introduction

The clinical assessment of feet is mostly based on the experience of foot experts, and varies with their clinical background.

To assess feet, experts typically use different techniques and equipment, such as podoscopes, blueprints, pressure plates, or goniometers.

To reach a better consistency among experts, it is necessary to compare their results to accurate, quantitative measurements.

Purpose of the study

This study aims to identify which clinical feet characteristics can be measured robustly visually, and which ones benefit from adding specific equipment in the measurement procedure.

As a first step, we want to identify which foot characteristics can be accurately predicted from the quantitative data from different measurement set-ups.

Methods

We measured 77 healthy subjects without major foot deformities. They were all clinically assessed by 10 experts (orthopedic technologists, podiatrists, and one orthopedic surgeon), hence a total of 770 assessments. Furthermore, an anamnesis was conducted, and gait of all subjects was quantitatively measured using three-dimensional (3D) motion analysis (Codamotion), dynamic pressure plate (RSScan International), a dynamic 3D scanner (ViALUX), and a force plate (AMTI).

To identify those clinical characteristics, which are robust over the different experts, we conducted a 2-agreement weighted kappa analysis which is an extension of Cohen's kappa for multiple raters (Warrens, 2012). Furthermore, we included both the popularity and the discriminative power of a characteristic (i.e. how many experts scored it and how diverse are the scores, respectively.). We included these last two elements because if either popularity or discriminative power are low, we cannot say much about a certain feature, e.g. if it is evaluated by only one or two experts, or if all subjects get the same score.

In a second part, we used the quantitatively extracted features (from the pressure plate, 3D motion analysis, dynamic 3D scanner, and force plate) to predict the average expert scores, for each clinical characteristic individually. To determine the best feature subset, we carried out a feature selection using the Lasso technique in a 10-fold cross validation. The feature subset was then fed to a support vector machine (SVM) classifier which trained a prediction model using a leave-one-out cross-validation.

Finally, from these data we can give an indication which hardware is best to predict foot characteristics. To this end, we built the SVM model only including features from one or a limited set of measurement equipment. In this abstract, we highlight three cases: prediction of the resting calcaneal stance position (RCSP), pressure of the midfoot during stance, and the ratio of the forefoot/heel width.

Results

Twelve foot characteristics were identified as being robust over all experts, including pressure of the midfoot during static measurements, the longitudinal foot arch height, the ratio of the forefoot/heel width, foot flexibility, and midfoot during midstance (supination/pronation). Furthermore, nine characteristics were considered to be moderately robust. In the rest of the study, we only consider these 21 (12 + 9) characteristics.

Figure 1 shows the prediction of the SVM model for foot flexibility. Each dot represents one subject's score of this feature. In the ideal case, when the SVM prediction is perfect, the dots will lie on the diagonal. We standardized

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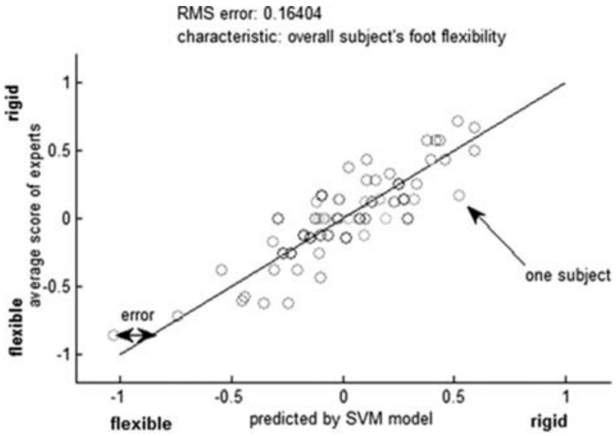

Figure 1. Comparison of the prediction of model and the score of the experts.

the range from −1 to 1, which corresponds to the case where all experts score the foot as flexible or rigid, respectively. The root-mean-square error is 0.164 which means that the model can give a good prediction of the experts' scores.

Of the 21 foot characteristics we took into account, 15 of them scored a RMS lower than 0.2 with the lowest being 0.124, and 6 were higher than 0.2, with a maximum of 0.449.

As expected, the prediction of the midfoot pressure was best using the pressure plate and was slightly improved when combining the pressure plate with a 3D scanner or 3D motion analysis. RCSP was best predicted using the 3D measurement system, or the 3D measurement system combined with the pressure data. Finally, the forefoot/heel ratio showed the best results combining 3D scanner data and pressure data.

Discussion and conclusion

We revealed some of the relationships between the clinical analysis of feet by experts and the measurements using specialized equipment.

The prediction using the quantitative features is dependent on the extracted features, so future work should focus on the foot characteristics that are difficult to predict, and extract better features for it.

Disclosure statement

No potential conflict of interest was reported by the authors.

Reference

Warrens, M.J. (2012). Equivalences of weighted kappas for multiple raters. *Statistical Methodology, 9*(3), 407−414.

Effects of shoe bending stiffness and surface stiffness on lower extremity biomechanics during running

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Introduction

Increasing the forefoot stiffness of footwear has been proposed as a method of reducing athletic injury risk while increasing performance. In terms of injury, footwear with increased forefoot bending stiffness limits the metatarsophalangeal (MTP) joint extension, thereby decreasing the potential of suffering a hyperextension injury of this joint (turf-toe). Additionally, increasing forefoot bending stiffness has been associated with improvements in sprinting and running performance (e.g. Stefanyshyn & Fusco, 2004). The majority of previous research on the effects of forefoot bending stiffness has been conducted on stiff surfaces. However, little is known regarding how the shoe bending stiffness and surface stiffness interact and if the potential exists to optimize shoe stiffness features for a specific surface stiffness.

Purpose of the study

To determine the influence of forefoot bending stiffness of footwear on lower extremity biomechanics during running on compliant and stiff surfaces.

Methods

Five male athletes performed in two footwear conditions (US size 9). Both shoes tested were identical adidas prototype soccer cleats that varied only in forefoot bending

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